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ABSTRACT

Collaboration in distributed settings has become a reality in organizational life, yet we still have much to learn. One important area of study is the integration of Collaboration Engineering (CE) in distributed, or virtual, teams. Collaboration Engineering offers promising guidelines for process structure, but its application in distributed environments is just beginning to be studied. We conducted a study in the design science tradition with the goal of examining whether and how the principles and techniques of Collaboration Engineering can be taken into a distributed setting. We report on the design, development, and feasibility test of a prototype environment that implements CE techniques for distributed teams. The study examined leadership and process structure effects on the development of shared understanding

1. An earlier version of this article was published in the proceedings of the 12th International Workshop on Groupware: Design, Implementation, and Use, CRIWG 2006, held at Medina del Campo, Spain.

in student teams working in a simulated organizational environment. Content analysis of qualitative data was combined with descriptive statistics of quantitative data to gain insight into participants' activities. We discuss the challenges of Collaboration Engineering in distributed environments and offer lessons learned and opportunities for future research.
Keywords: *Collaboration engineering, distributed teams, virtual teams, shared understanding, process structure, leadership, thinkLets.*

INTRODUCTION

Organizations operate in an environment that requires rapid response and adaptability, which often means an increasing use of distributed teams and virtual work. The challenges of working in virtual teams include such issues as trust, communication, participation, coordination, and effectiveness (Pinsonneault and Caya, 2005; Powell, Piccoli and Ives, 2004). At the same time, technological support for distributed teamwork has evolved considerably (Khazanchi and Zigurs, 2006; Munkvold and Zigurs, 2005). However, one of the most significant challenges in traditional teams still remains an issue in distributed environments, namely the processes that team members use to achieve maximum effectiveness for different tasks. We still have much to learn about which types of support tools and structures can be provided for distributed teams so they can select and carry out appropriate processes themselves, without reliance on facilitators.

Collaboration Engineering methods and techniques have been developed to address this important issue, via the capture and design of successful repeatable collaboration processes (Vreede and Briggs, 2005). Collaboration Engineering (CE) began in the context of same-time same-place meetings, addressing the design of recurring collaboration processes that team members could use to reach their goals. Prior CE research has been done primarily using Group Support Systems technology in face-to-face situations (Harder, Keeter, Woodcock, Ferguson, and Wills, 2005; Hengst, Kar, and Appleman, 2004; Vreede and Briggs, 2005). The methods and techniques of Collaboration Engineering have not yet been applied in distributed environments to any great extent. Yet it is likely that process structure is even more important for virtual teams because of the difficult challenges they face (Pinsonneault and Caya, 2005; Powell et al., 2004). Thus it is important to study the question of whether and how the principles of Collaboration Engineering translate to distributed environments.

The current study was conducted in a design science tradition (Hevner, March, Park, and Ram, 2004), with the goal of examining whether and how the principles and techniques of Collaboration Engineering can be taken into a distributed setting. (We use the terms "distributed" and "virtual" interchangeably throughout the article.) The article describes the design and development of a new environment for supporting process use in virtual teams. We also report the results of an initial study that was conducted to test the feasibility of the environment. The study was designed to examine concepts that are both important and especially difficult in virtual teams, namely the achievement of shared understanding through process use and team leadership. Content analysis of qualitative data was combined with descriptive statistics of quantitative data to gain insight into participants' activities. Participants were teams of students working in a simulated organizational environment as part of the course assignments.

The article contributes in several ways. First, we show how and whether the successful method of Collaboration Engineering from face-to-face environments translates to virtual teams. Second, we provide a specific technology implementation of these concepts that shows how existing tools can be enhanced to create specific options based on a theoretical foundation. Finally, we add to the literature on virtual teams by showing how the process structure supplied through Collaboration Engineering impacts key aspects of virtual team communication.

The next section describes the basic concepts of Collaboration Engineering and discusses the particularly challenging aspects of virtual teams in which Collaboration Engineering might make a difference. Then, we provide a detailed design for integrating technology with process in a distributed environment. We follow with a detailed description and analysis of the initial study that was conducted in this custom-designed environment. The article concludes with discussion of issues and implications for research and practice in the application of Collaboration Engineering in distributed teams.

CONCEPTUAL BACKGROUND

Purposive Processes through Collaboration Engineering

Collaboration Engineering (CE) is an approach that directly addresses the process challenges of collaborative work in a systematic way (Briggs, Vreede and Nunamaker, 2003). CE is defined as "an approach to designing collaborative work practices for high-value recurring tasks, and deploying those designs for practitioners to execute for themselves without ongoing support from professional facilitators" (Briggs, Kolfschoten, Vreede, and Dean, 2006, p. 1). The CE approach provides methods and models to design repeatable and predictable collaboration processes. The cornerstones of CE are process objects called thinkLets, which can be combined to create ("snap together") a team's collaboration process. A thinkLet is "a named, packaged facilitation technique captured as a pattern that collaboration engineers can incorporate into process designs" (Vreede, Kolfshoten, and Briggs, 2006, p. 1). A thinkLet represents a facilitator's best practice. Each thinkLet addresses a particular pattern of collaboration, that is, a generic activity that teams need to undertake in order to accomplish collaborative tasks. The instantiation of these patterns in teams enables purposive process structures that can help teams execute collaboration processes and achieve predictable interaction among team members that helps to assure better team performance. Taken together, the thinkLets can be considered a CE pattern language (Vreede et al., 2006).

ThinkLets support six fundamental patterns of collaborations that have been identified and defined as follows (Briggs et al., 2006):

1. **Generate**: moving from having *fewer concepts* to having *more* concepts.
2. **Clarify**: moving from *less* to *more shared understanding* of the concepts under consideration and of the words and phrases used to express them.
3. **Reduce**: moving from having *many concepts* to a *focus* on *fewer concepts* worthy of further attention.
4. **Organize**: moving from *less* to *more understanding* of the *relationships* among concepts.
5. **Evaluate**: moving from *less* to *more understanding* of the *relative value* of the concepts under consideration.
6. **Build consensus**: moving from having *fewer* to having *more group members* who are willing to commit to a proposal.

Team members can use combinations of these patterns of collaboration as they work to achieve their goals. For example, a team might start with generating ideas (generate), clarifying those ideas (clarify), organizing those ideas into several categories (organize) or evaluating their values (evaluate), and then conclude with trying to achieve some level of agreement (build consensus).

A specific pattern, such as idea generation (generate), can actually be carried out in a variety of ways (Kolfschoten, Briggs, Vreede, Jacobs, and Appleman, 2006). The thinkLets referred to earlier embody the techniques that guide teams in specific details on how to carry out a given pattern. Each thinkLet consists of a description of steps that people have to say, do, decide, and remember throughout the execution of the thinkLet in order to produce the desired pattern of collaboration. With that detail, teams can proceed with their collaboration in a more systematic way and on their own (Kolfschoten, Hengst, and Vreede, *in press*). Each thinkLet also includes decision criteria for selecting it as well as situations where it should not be used (Vreede and Briggs, 2005). For example, a FreeBrainstorm thinkLet has the following selection criteria description (ibid, p. 7):

> *"Choose this thinkLet when it is important to create a shared understanding of the problem among people with different perspectives, expertise, or background."*

and the following description of when not to use it (ibid, p. 7):

> *"Do not choose this thinkLet to maximize the number of creative ideas a group produces. Consider DirectedBrainstorm instead."*

In summary, the CE principles and the thinkLet design patterns provide a systematic approach to structuring and coordinating team process (Kolfschoten et al., 2006).

The way in which a collaboration process is carried out has been shown to be essential to the performance of virtual teams (Massey, Montoya-Weiss and Hung, 2003). Clearly, the application of CE principles in distributed environments directly addresses this all-important factor. Yet, CE studies in distributed environments are relatively rare. We found only one study that tried to use CE in a distributed setting (Appelman and van Driel, 2005); that study focused on designing and executing a process that could shorten the steps in a crisis situation. The next section examines what is known about virtual teams on specific issues that are both important and especially relevant for CE.

Virtual Teams

Virtual teams are an essential part of today's global environment (Powell et al., 2004). Virtual teams have been defined as "groups of geographically, organizationally and/or time dispersed workers brought together by information and telecommunication technologies to accomplish one or more organizational tasks" (ibid, p. 7). Therefore, a virtual team by definition has a high reliance on information and communication technologies (ICTs) (Dubé and Paré, 2004). At the same time, the lack of face-to-face interaction may require an increase in efforts to foster interaction, inclusion and participation (McGrath, 1991), including sharing social information to help develop strong relational links (Chidambaram, 1996). Reviews of research on virtual teams have identified key issues relating to effective outcomes (Dubé and Paré, 2004; Powell et al., 2004). We discuss the following issues as having the greatest potential for support from CE: trust, shared understanding, leadership, relational development, task-technology interaction, and performance.

Trust. Swift trust was one of the first phenomena to be studied in the context of virtual teams. Swift trust occurs because the lack of face-to-face interaction in virtual teams causes team members to assume that other members are trustworthy while seeking confirming or disconfirming evidence during their interaction (Jarvenpaa and Leidner, 1999; Meyerson, Weick, and Kramer, 1996). Confirming events are clearly desirable, since they lead to the persistence of trust in teams. The process structure that is provided by CE techniques creates predictable interaction patterns and consistent communication within the team. This predictability has potential to contribute to on-going reinforcement of trust in virtual teams.

Shared Understanding. Shared understanding is another important but difficult state to achieve in virtual environments. Shared understanding can be defined as a convergence on a common set of reactions to stimuli. Virtual environments challenge development of this convergence for several reasons, including limitations on communication imposed by technology (Sproull and Kiesler, 1986), lack of mutual knowledge and shared language among members (Cramton, 2001; Qureshi and Vogel, 2001), and cultural differences (Kayworth and Leidner, 2000; Sarker and Sahay, 2002). Again, the systematic and predictable process patterns that are provided by CE techniques give the team a shared language for process, which has potential to increase shared understanding.

Leadership. Effective leadership is a necessary condition for team coordination, which is positively related to team performance (Johansson, Dittrich and Juustila, 1999). The lack of face-to-face interaction can hinder leaders in asserting their leadership functions. Some empirical work has been done on leadership in virtual teams, e.g., in relation to leadership styles (Kahai, Sosik, and Avolio, 2004), confirming the negative impact of ineffective leadership (Kayworth and Leidner, 2001-2002), and showing how leaders emerge (Yoo and Alavi, 2004). Leadership roles in virtual team can be supported by providing collaboration norms (Sarker, Lau, and Sahay, 2001) and coordination protocols (Malhotra, Majchrzak, Carman, and Lott, 2001). CE techniques address both the norm and protocol issues by providing a common language, process, and point of view when it comes to carrying out collaboration patterns. These techniques can potentially give leaders a systematic way to carry out effective coordination in virtual teams.

Relational Development. Virtual teams take longer to develop relational links (Chidambaram, 1996). Those who try to shorten or skip this developmental process face a range of negative outcomes, such as lack of an integrated product, lack of ownership of the final result, lack of team bonding and commitment, polarization of some members, and trust problems (Munkvold and Zigurs, 2007). The exchange of social information can help team members to develop relational links (Warkentin and Beranek, 1999), but computer-mediated teams tend to focus more on task rather than on relational or social activities (Chidambaram, 1996). Although existing CE techniques primarily focus on task-related processes, these techniques can also be specifically designed to promote relational development. Explicit attention to social exchange can be built into a designed collaboration process through the use of thinkLets.

Task-Technology Interaction. Much has been written about the interaction of task with technology, that is, how different technology capabilities might best be matched to different team tasks. For example, task types based on complexity have been matched with technology dimensions supporting communication, information, and process to define ideal fit profiles (Zigurs and Buckland, 1998). Adaptive structuration has been proposed to explain how appropriation support in the form of guidance, facilitation, or training affects the basic task and technology fit profile during group interaction (Dennis, Wixom, and Vandenberg, 2001). Overall, it appears that there are circumstances under which teams are able to adapt to available technology (Hollingshead, McGrath, and O'Connor, 1993) and/or adapt or tailor the technology itself (Germonprez, Hovorka, and Collopy, 2007). CE techniques have potential to create more integrative task and technology patterns because thinkLets define both aspects of a collaboration process in unison (Kolfschoten et al., 2006). This integration has yet to be explored but is a potentially powerful form of task-technology fit.

Performance. Finally, there is the issue of virtual team performance or outcomes in general, including not only effectiveness but also satisfaction and continuing commitment to the team. Although virtual teams generally perform about the same as traditional teams, the factors that contribute to positive virtual team outcomes include training (Kaiser, Tullar, and McKowen, 2000), team building (Kaiser et al., 2000), developing shared language (Majchrzak, Rice, King, Malhotra, and Ba, 2000), and coordination and commitment of the team (Maznevski and Chudoba, 2001). Through the effects described in the earlier discussion of trust, shared understanding, leadership, relational development, and task-technology interaction, CE has significant potential to enhance outcomes in virtual environments.

Collaboration Engineering and Virtual Teams

CE offers an important way to enhance and support collaboration by focusing on process challenges. We have described key challenges that virtual teams face and discussed briefly how CE techniques might address those challenges. Given the heavy reliance of virtual teams on information and communication technologies, special attention to the integration of process with technology is needed. Existing theories of task-technology fit show that teams need a portfolio of technology capabilities and flexible support for different tasks and processes (Dennis et al., 2001; Zigurs and Buckland, 1998). Being able to define an integrative approach to process needs and technology capabilities in a virtual environment would go a long way toward supporting effective outcomes. The next section describes the design and development of a specific implementation of a distributed environment that applies the principles and techniques of CE.

TECHNOLOGY AND PROCESS ENVIRONMENT

The design and deployment of collaboration processes for distributed environments follows from the issues discussed earlier. From a task perspective, a team should be able to achieve a common view of what needs to be done to accomplish its goal. Thus, the collaboration technology must support task management by providing calendar tools, agenda tools, project planning tools to track milestones, and alerts to notify team members of new or changed information. Obviously, these features are also beneficial for traditional teams, but we argue they are even more critical for the success of virtual teams, given existing evidence on process issues that was discussed in the previous section.

From the perspective of relational development, team members should be able to develop a common set of norms, expectations, and values, as well as being able to see how they individually fit within the larger collective in terms of their roles, knowledge, skills, and abilities. Thus, the collaboration technology must support a variety of communication and coordination capabilities such as document sharing, discussion boards with

Table 1. Technology Capabilities to Support Collaboration Needs

	Task Support	Relational Development	Process (thinkLet) Support
Communication			
Document sharing	x		
Discussion board - Threaded discussions	x	x	x
Instant messaging		x	
Workspace chat rooms		x	
Voting	x		x
Simultaneous input	x		
Presence awareness		x	
Coordination			
Task management	x		
Calendar tools	x		
Agenda tools	x		x
Common project plan	x		
Alerts	x		
Synchronization	x		
Persistent group memory	x	x	x

threaded discussion, instant messaging, workspace chat rooms, voting, simultaneous input, presence awareness, synchronization, and persistent group memory.

The features just discussed are basic capabilities for a team's general needs (Munkvold and Zigurs, 2007). Most importantly, from a process perspective, support is needed for all six patterns of collaboration. In this case, the environment should have at least the following features: (1) a shared discussion board; (2) ability to comment on each of the entries on the board; (3) ability to remove entries; (4) ability to move entries into separate categories; and (5) ability to express preferences (vote). Agenda tools also support process by allowing a sequence of thinkLets to be built for tasks requiring multiple steps. These fundamental characteristics can be used to implement the thinkLets that provide process support.

Finally, the environment should meet basic requirements of ease of use and access. As a starting point for our specific implementation, we were also seeking to develop an environment at low cost, which implies starting with an existing infrastructure that we could enhance with custom development. As researchers, we also needed to be able to capture group discussion through logs of messages exchanged through the virtual environment.

Table 1 summarizes the requirements for technology support in terms of all these criteria.

We chose Groove™ as the technology infrastructure for our implementation because it best met the evaluation criteria from among the options we examined and it provided an opportunity to create a new environment with adaptability for future work. As a peer-to-peer (P2P) based system, Groove™ has several advantages. While a client-server system would store data in a central location, in a peer-to-peer system, every peer or node acts as both client and server and provides part of the overall information available from the system (Aberer, Punceva, Hauswirth, and Schmidt, 2002). A synchronization process is an important part of P2P technology to keep information for every team member up-to-date.

We implemented the following six thinkLets (process objects) in Groove™, each of which covers one of the six patterns of collaboration that were discussed earlier (pattern name is in parentheses):

- LeafHopper: gather ideas on a number of topics simultaneously (Generate)
- FocusBuilder: arrive at clearer descriptions of key ideas (Clarify)
- BroomWagon: select the key contributions from a larger set (Reduce)
- PopcornSort: organize a set of ideas into a set of categories (Organize)
- StrawPoll (3pt): take a vote on a set of proposals or options (Evaluate)
- CrowBar: explore reasons for differences of opinion (Build Consensus)

The thinkLets were chosen based on the ease of their execution by distributed team members and their usefulness in supporting a broad set of tasks, given the general nature of the patterns. Each thinkLet was implemented as a separate and custom tool in Groove™, using Groove™'s generic Outliner tool. Consistent with principles of CE, we also created guidance for each thinkLet. First, we provided a high-level description for the types of activities that could be supported by each thinkLet. Second, each thinkLet included a template with sample information that illustrated the results of using the tool. Finally, a separate tool in Groove™ was populated with more elaborate instructions for each thinkLet, which included guidance selection and a detailed step-by-step script that team members or the team leader could follow.

Figure 1 shows the implementation of the LeafHopper thinkLet in our Groove™ environment. Figure 2 shows the guidance for executing the LeafHopper thinkLet which a team sees during the actual execution of the thinkLet by a team.

To accelerate the development of relational links, i.e., closeness or intimacy among group members, we designed a custom tool called "Meet and Greet." Through initiating interaction in this forum, team members can "break the ice" and get to know their teammates better. This feature is critical for team members who are collaborating from different geographical boundaries with no prior experience of working together, and it directly addresses the issue of relational development that has been emphasized in the research on virtual teams.

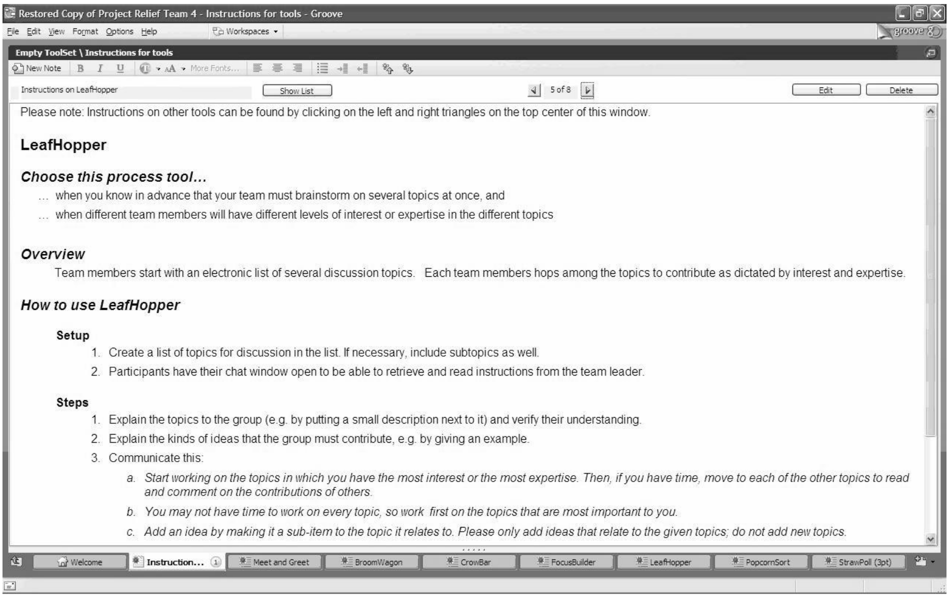

Figure 1. Implementation of LeafHopper thinkLet in Groove™

FEASIBILITY STUDY OF DISTRIBUTED COLLABORATION ENGINEERING

We tested the distributed environment that was described in the previous section through an initial study that was designed to assess feasibility, as applied in the context of key issues for virtual teams. We chose issues that were particularly salient, per our earlier discussion. Specifically, we studied leadership and shared understanding, but primarily we were interested in how the teams would utilize the collaboration tools provided to them in this custom-designed environment.

Overview of Study

The study involved participants from geographically-distributed universities who had to work together on a time-intensive project using the Groove™ collaboration environment. The context was an emergency response scenario, and the teams were assigned the task of developing the requirements for a Web site to assist people who were providing disaster relief. Each participant played an assigned role: government official, utility infrastructure superintendent, police officer, aid organization representative, and information system developer. Collaboration was necessary because each role represented a different constituency or agency with difference preferences for what should be included in the deliverable. Since the deliverable could only have a limited number of items for the Web site design and those items had to be prioritized, team members would have to collaborate to find the best way to integrate their incongruent goals while at the same time satisfying the constituents they represented.

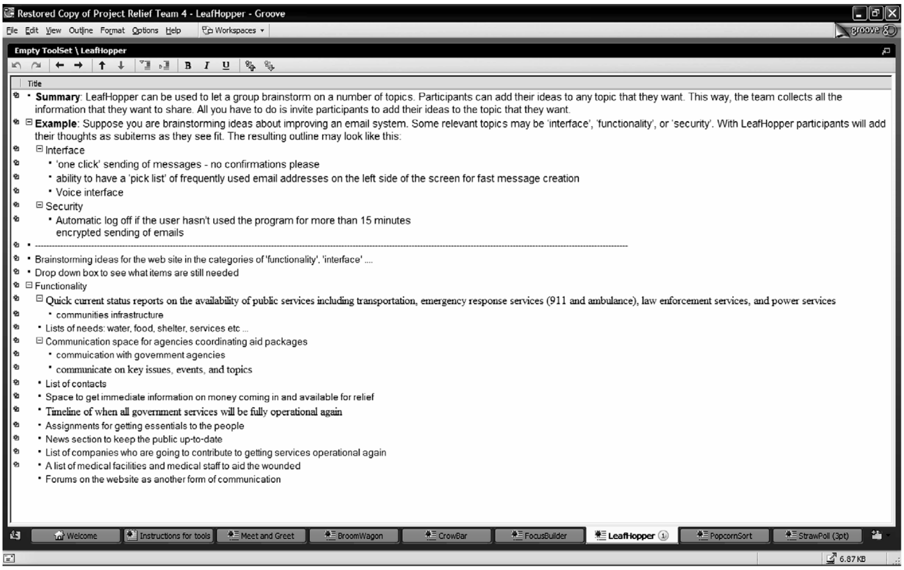

Figure 2. Guidance for Using LeafHopper thinkLet in Groove™

Participants were students from three different universities who received extra credit in their courses for completing the study. Thus the study is what is sometimes called a "quasi-field" study because it involves an educational setting but the task is realistic in terms of what a student might encounter in a work environment. In addition, the team processes required to carry out the task are the same general types of processes that occur in decision-making in work environments.

Boundaries and Limitations of Study

The study is limited in its generalizability because of the use of student participants who were playing roles, as opposed to having disaster relief officials in real scenarios. However, our goal was not to achieve generalizability, but instead to examine how CE techniques might work in distributed environments, thus the use of participants with a general understanding of decision and team processes is appropriate. The small number of participants and teams that completed the study is also a limitation, but again we were testing the feasibility of this approach for the first time. A final limitation is that we did not measure effectiveness or quality of the deliverables. Clearly, it would be desirable to link the effective use of CE principles to improved outcomes, but we deferred that goal to later research, focusing here just on the basic feasibility of the environment.

Design Details

We formed fourteen five-member virtual teams, assigning students randomly to teams in two different treatment conditions: assigned leadership and shared leadership. The purpose of having different leadership conditions was to highlight potential differences in how teams would use available collaboration tools in the distributed environment. In the assigned leadership condition, the participant playing the role of government official was chosen as the leader. To eliminate potential confounding from gender differences, the government official role in each team was played by a male participant. In the shared leadership condition, all team members received instructions that they should all share the tasks that a leader would normally undertake, and examples of leadership tasks were provided to all participants.

Task Instructions

Team members were e-mailed a detailed handbook for the study, which included a description of the project, details and deadlines for project deliverables, description of the technology environment, details for the role being played by that person, and specific steps for carrying out the project. The instructions emphasized that the team had to agree on the requirements for developing the Web site, while at the same time satisfying each person's (role's) constituency. The fictional disaster scenario was adapted from research on creative ideation using electronic brainstorming (Santanen, 2001). To introduce realistic constraints and the need for discussion and consensus, the teams were limited to a small number of features that could be incorporated into the Web site. Teams had one week to perform the task and turn in their deliverable. Upon joining their team in the Groove™ workspace, members were instructed to introduce themselves by posting information on the "Meet and Greet" forum.

Technology and Process

Groove™ was chosen because it best met the fundamental criteria for a distributed environment (as listed earlier in Table 1). In addition, it presented a novel opportunity for the students to interact in a new way and learn a new tool. Groove™ supports presence awareness, which allows members to recognize when other team members are active in the collaboration environment. It also enables simultaneous input from multiple members of the team. Because members continuously update the team workspace throughout the duration of the task, the notification capability within Groove™ allows group members to quickly recognize which items have been added or updated since their last entry into the environment.

As noted earlier, the collaboration environment had to support all six patterns of collaboration, namely generate, clarify, reduce, organize, evaluate, and build consensus (Vreede et al., 2006). The generate pattern requires the ability to share ideas in the same workspace. The clarify pattern requires the capability to expand, clarify, and edit existing ideas in the workspace. The reduce pattern requires the capability to select the ideas from a larger set of ideas. The organize pattern requires the capability to group and display

Table 2. Team Descriptions by Leadership Condition

Issue Addressed	Message Received	Percent of Total
Task	19	40.4%
Team	15	31.9%
Technical	13	27.6%

ideas in a structured manner. The evaluate pattern requires the capability to place value or describe importance on ideas. The build consensus pattern requires the capability for group members to build agreement on ideas. The capabilities needed for the thinkLets to support these patterns could all be implemented via the Outliner tool in Groove™.

Data Collection

A pre-session questionnaire captured demographics of participants, as well as their existing perceptions of virtual work. A post-session questionnaire measured participants' perception of shared understanding and satisfaction after the completion of the deliverable.[2] Transcripts of each team's communication via Chat on the Groove™ workspace were saved for later use in analyzing team interaction. Workspaces of each team were saved for analyzing how the team utilized the thinkLets provided. Message exchanges between team members and researchers were recorded to analyze concerns raised by participants throughout the study. Team deliverables were saved for providing feedback on team performance to the students carrying out the task.

Descriptive Data and Message Types

Table 2 shows information about the teams by leadership condition, including the number of teams that completed the required deliverable and used different capabilities within the collaboration environment. Even though six of the teams tried to utilize the thinkLets as collaboration tools, we could debate whether they used the tools correctly or not. The only thinkLet that was used by every team that used thinkLets was LeafHopper, which supports the generate collaboration pattern.

A content analysis of exchanged messages was done, in which we identified each comment and coded it as belonging to the following categories: (1) task; (2) team; and (3) technical. The task category refers to participants' messages discussing the task, including but not limited to deadlines and meeting appointments. Team issues refer to messages complaining about team work or other team members, e.g., no other member joined the team. Technical issues refer to messages about problems in using the technol-

2. Detailed descriptions of the thinkLets and the post-session questionnaire are available by request from the first author.

Table 3. Categorization of Messages Based on Content

Issue Addressed	Message Received	Percent of Total
Task	19	40.4%
Team	15	31.9%
Technical	13	27.6%

ogy, e.g., inability to see other team members. Table 3 shows the number and percent of exchanged messages that fell in each of the three categories. The greatest percentage of messages related to task, followed by messages relating to team and technical issues.

A high percentage of task-related messages is a good sign, since it suggests that teams were working on the task as required. A high percentage of team-related and technical-related messages, on the other hand, suggests that teams might have had problems in performing their task. An examination of the content of these messages revealed that most of the time team members were concerned about their teammates not joining the team. When their teams were incomplete, members asked for guidance from the researchers in how to proceed. Although a complete team is obviously an ideal condition, team members needed to know how to proceed in such a case. We observed that not knowing how to proceed frustrated members who had already joined the team. This frustration could be one of the reasons why participants only showed a mediocre satisfaction level at the end of the study. Table 4 shows the means by treatment condition of satisfaction with the process and satisfaction with the outcome, where a score of 1 means less satisfied and a score of 7 means more satisfied. Participants seem to prefer clear instructions on how to proceed, which is associated with the assigned leadership condition.

CHALLENGES IN DISTRIBUTED COLLABORATION ENGINEERING

CE has proven to be helpful for face-to-face collaborative work in guiding people through a systematic way of accomplishing that work. Challenges for same-time same-place collaboration can be addressed through combining different patterns of collaboration and incorporating thinkLets to achieve predictable interaction among participants to accomplish one step at a time. Still, participants need to design processes for their team and to execute that design to accomplish their task. For each of the collaboration patterns, there are different choices of thinkLets or process objects that can guide teams in specific details on how to carry out a given pattern.

Structuring the right process and choosing the appropriate thinkLets are critical for CE design (Vreede and Briggs, 2005). Moving those activities into a distributed environment adds complexity to the process found in face-to-face collaboration. Our study indicated that it is still challenging for virtual team members to take advantage of CE concepts and techniques. Not only is the concept novel, as noted in one participant's

Table 4. Means of Post-Session Satisfaction Scales by Leadership Condition

Construct	Assigned Leadership	Shared Leadership
Satisfaction with Process	3.08	2.60
Satisfaction with Outcome	3.43	2.40

question (*"How do we actually use the tools such as LeafHopper?"),* but virtual teams also face issues related to technical problems, communication problems, and coordination problems. It was also clear that providing training is essential to helping virtual team members to become familiar with thinkLets, even though they represent familiar collaboration patterns. Participants' messages indicated that some of them had problems with the technology infrastructure and the thinkLets that were provided within it. It seems that improvements are still needed in the technological environment, even though new features and tools keep appearing in the marketplace.

Challenges in communication were reported by several participants. In their feedback at the end of the study, participants reported concern with a lack of face-to-face interaction (*"I didn't like not being able to meet face to face"*) and ineffective leadership (*"...it was unclear as to who was running the groove tools and who was leading"*). Furthermore, a lack of mutual knowledge was evident among team members (*"I was confused at first and did not really know what the task was"*).

We noted earlier that coordination norms need to be established in order for a virtual team to achieve good performance (Sarker et al., 2001). One participant expressed her feelings about this lack of coordination (*"I was pretty much lost through the whole thing. It was confusing how to communicate with the other team members"*). Although detailed instructions in how to use Groove™ were given, still many participations complained (*"A lot of the instructions seemed vague. I got all the software going and I hit a dead end. I worked on it for a couple of hours and could not make any progress"*).

The problems that were identified complicate the design of a team process as well as the execution of that design by team members. Additionally, in virtual teams, members need to make sure they have developed relational links in order to avoid negative outcomes. After that, they can work together to: (1) understand the problem; (2) develop alternative solutions; (3) evaluate alternatives; (4) choose alternatives; (5) make a plan; as well as (6) take action; and (7) monitor results. Each of these steps can incorporate several collaboration patterns and have its own deliverable. Team members have to agree on how to structure processes in order to achieve each of the deliverables. Reaching this agreement in distributed environments is more challenging, since it requires coordination and extensive communication. This is especially true in cases where there is no clear leadership in the team. Once everybody agrees on how to go forward, they can choose thinkLets that will help them in carrying out a specific collaboration pattern. For a virtual team that relies solely on asynchronous communication, utilizing a thinkLet could become a challenge, especially for some collaboration patterns. Based on the experiences in our study, we speculate that specific patterns may be more challenging than others.

As a team starts with generating ideas (the generate pattern), members can contribute by writing their ideas in the shared workspace. This activity does not require extensive communication among members, since members will mainly focus on their own ideas or build on other members' ideas. Only a low level of coordination is needed, such as in determining the amount of time for this activity. Therefore, we speculate that this pattern of collaboration can be applied in distributed settings without significant problems.

After collecting ideas from members, teams need to clarify some, if not all, of the ideas in order to gain more shared understanding. This pattern of collaboration (clarify) is likely to require more extensive communication among members as well as more coordination. In a distributed environment, this activity would be difficult or complicated to accomplish if the team has to rely solely on asynchronous communication. Extensive communication is needed, since members will have to go through all their ideas and try to gain more shared understanding for each of those ideas. The clarify pattern involves discussion that would be difficult to carry out solely through asynchronous communication. Coordination is needed to make sure that this discussion will not lose focus or turn into a heated debate that could jeopardize the team's well-being. Therefore, performing this pattern of collaboration in distributed settings is likely to be challenging, unless team members arrange for synchronous communication.

With a broad shared understanding, teams can try focusing on fewer ideas worthy of further attention (reduce). This pattern requires communication among members to make sure that they agree on the ideas to be considered. However, their communication is likely to be less intense than in the clarify pattern, since team members have already acquired shared understanding on those ideas. Coordination is needed to keep members focused and to move this process forward by staying on time. This activity can be performed in distributed settings without great challenges, as long as members have established shared understanding. However, if the team has not gone through a clarifying process, this activity could also become challenging.

Teams can organize ideas into categories based on certain relationships. This may require extensive communication among members. If not done beforehand, they have to agree on categories to be established. They also have to agree on which ideas belong to which categories. Coordination is helpful to move a team forward by guiding members through steps for organizing process. However, in distributed settings, synchronous communication may be needed, since it is better if members work together in assigning ideas to existing categories based on their shared understanding. Relying solely on asynchronous communication could complicate the process of gaining shared understanding and keep the team from accomplishing this activity efficiently.

Team members can evaluate existing ideas in order to prioritize them. This activity can be accomplished by asking members to vote on existing ideas. This voting would help in separating ideas based on members' perception of priority. Communication among members is relatively low in this pattern. Coordination in this activity is mainly geared toward defining rules for this process. Once team members agree on the rules, they can carry them out without big obstacles. In distributed settings, it appears that this activity can be accomplished smoothly without much discussion.

Consensus building is the most difficult activity, since it involves reducing disagreement among members. Reducing disagreement would require extensive communication among members as well as effective coordination to avoid hostility in the team. Therefore, for virtual teams, this activity is likely to require synchronous communication and effective moderation from a team leader. If members rely only on asynchronous communication, they will be less likely to come to a consensus and to accomplish their task. Poor coordination could also have an impact on team well-being and lead to negative outcomes.

Figure 3 shows the six collaboration patterns based on their relative communication and coordination intensity. Collaboration patterns that require only low communication and coordination intensity can be supported in distributed settings with relatively little difficulty. However, those with high communication will require synchronous communication among team members, requiring the technology platform for the virtual team to support both synchronous and asynchronous communication.

Many of the participants in our study chose synchronous communication via online chat to work on their task. This practice suggests that that it was difficult for team members to carry out their task based solely on asynchronous communication. This choice is also consistent with Powell et al.'s (2004) notion that technologies supporting synchronous communications are needed for supporting ambiguous tasks, as we had in our study. This relationship is only suggested in the current research, however, and re-

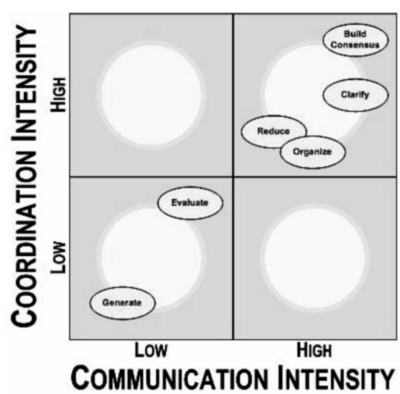

Figure 3. Coordination and Communication Intensity for Collaboration Patterns in Virtual Teams

quires further verification. Indeed, Figure 3 represents a testable set of propositions for further confirmation, beyond the basics of our existing argumentation about virtual teams and the results from the initial study.

IMPLICATIONS AND CONCLUSIONS

We have presented the design and implementation of a specific Collaboration Engineering environment in a distributed setting and the results of a feasibility study of its application. Our study is unique in that this is the first attempt to apply CE in a distributed setting using Groove™ as a platform. We have shown that thinkLets or process objects can be implemented in this technology. We were able to verify issues related to virtual teams as developed in prior research, e.g., the relationship between technical issues and satisfaction level, communication challenges, and task and technology. The study was conducted in a design science tradition, using a simulated organizational task with student participants.

The study provides lessons learned for researchers, virtual team members, and designers of virtual team process and technology. As *researchers*, we sought to examine whether the CE principles and techniques could be implemented in a specific environment of our own design. Differences in collaboration technologies and their effects have been discussed in the literature for some time now. What is different in a virtual environment is how closely bound the technology is with the process objects (thinkLets). Ever since the early days of Group Support Systems, process structure has been shown to be a significant benefit for groups that are able to incorporate it into their work practice. Yet much of the research on collaboration technology has focused on communication patterns or group characteristics, rather than on specific process structures. As researchers, we learned that significant attention still needs to be given in helping groups understand how process and technology together can help them work to achieve their task. CE principles provide a way to develop a coherent program of research around this issue. This tight binding of technology with process is a key aspect of virtual teams and, we argue, an area where CE can really contribute.

For *virtual team members,* we emphasize the need for training and continual reinforcement of the types of processes that are most helpful for different tasks. In this study, team members found it difficult to get up to speed quickly on what the collaboration environment had to offer. The environment was quite new for everyone, both in terms of the application and the process that was embedded in that application. But in addition to training on specific tools, it may be a good idea to have "pre-training" on virtual team membership itself, in the form of an intervention to get team members thinking differently about what virtual environments offer. This training can be implemented in a process object that can be invoked whenever a team starts working virtually, as a reminder of the specific things to which they need to pay particular attention.

Designers of collaboration processes and technologies need to be concerned not only with specific instructions for using a process, but with how process objects (thinkLets) can be combined into a meaningful sequence of activities that are appropriate for the task at hand. If the idea is to be able to empower group members to conduct their own session without benefit of facilitation, then process objects need to have built into them some guidelines for which objects "belong naturally" with which other objects in terms of sequence, as well as which objects are best associated with what types of tasks (see also Kolfschoten et al., 2006). Similarly, the repeatability of process objects in a distributed setting needs to be examined more closely. One important question is the extent to which the virtual context affects the repeatability of a specific process. The relative intensity of coordination and communication needs that was depicted in Figure 3 suggests areas where special attention needs to be paid to technology support.

The distributed collaboration environment that we designed and implemented offers several opportunities for future research. From a *single task* perspective, the environment can be used to allow teams to collaborate following one of the six patterns of collaboration. Researchers could study, for example, how groups perform using different reduction techniques, or, how different generation techniques yield more or less creativity. Researchers could also investigate how scalable amounts of task structure impact team performance, for example, by comparing the performance of teams receiving different levels of process training and guidance during the execution of a consensus building task.

From a *multi-task* perspective, the environment allows for different levels of structure. For example, researchers could use the environment to test a predefined sequence of activities. Many organizations, such as in the financial services industry or the military, desire a standard process for a collaborative work practice. When designing such a standard work practice, testing a prototype collaboration process in a series of experiments is an invaluable way to gain insights on the strengths and weaknesses of the proposed process. Researchers could also use the environment to test emergent activity sequences. Many collaborative efforts, especially those involving collaboration between stakeholders working under time pressure from different locations, require a team to decide on its course of action as time progresses. Consider, for example, a rapid response team in a crisis situation that has to deliberate and decide on relief efforts at the same time that their understanding of the situation is changing constantly. The collaboration environment could support such teams by allowing them to create ad hoc processes by choosing appropriate collaborative process objects in an emergent fashion. However, the environment's potential goes further in that it allows researchers to study emergent collaborative work practices over time and use pattern recognition techniques to identify best practices in successful distributed teams.

The key issue in this article was the question of how well CE principles and techniques translate to distributed environments, including the ease with which we can develop and implement a flexible infrastructure for the use of a broad range of process objects. We showed that it is possible to use a peer-to-peer application as the foundation for creating a collaboration environment that can then be used in different ways by different teams. However, our results reinforced that distributed teams need considerable effort in order to get up to speed with being able to use and adapt processes for themselves. This feasibility test of CE, in this one specific environment, shows that there is interesting work yet to be done on the best ways to integrate collaboration tools with group process in order to help virtual teams perform rapidly and effectively across a wide variety of tasks.

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